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Measuring systemic problems in National Innovation Systems. An application to Thailand

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ABSTRACT

The paper contributes to research on innovation systems in general and, in particular, to the current debate on rationales for innovation policy by providing a framework to identify systemic problems in a given system of innovation and test the framework empirically. The data were drawn from the Thai Community Innovation Survey in the period after which a major change in the country's innovation system policy had been initiated. By hierarchical factor analysis, systemic problems are identified and grouped into four components: institution, network, Science and Technology infrastructure and other support services. The analysis allows researchers to investigate the mismatch between policies and problems and identify policy gaps.

1. Introduction

Innovation system (IS) research is increasingly important to innovation policy making. Since the approach was flagged by the OECD in the mid nineties, an increasing number of governments have adopted IS explicitly in their innovation policies (Mytelka and Smith, 2002). However, applying the concept in practice is a daunting task (Chaminade and Edquist, 2006, 2010). Policies based on the IS approach often collide with old paradigms, rationales and instruments (Intarakumnerd and Chaminade, 2007) and, more often than not, end up being one-size-fits-all-policies rather than policies that take the specificities of the system into account.[1] One of the reasons for this is that we know too little about how to *identify* and *measure* specific problems in the system (if at all possible), despite several fruitful attempts to *define* them.

The literature on national systems of innovation (Lundvall, 1992; Edquist, 1997; Nelson, 1993; Freeman, 1987) and more specifically the strand of literature dealing with rationales for innovation policy (Lipsey and Carlaw, 1998; Smith, 2000; Chaminade and Edquist, 2006), has defined systemic problems as systemic imperfections that might slow down or even block interactive learning and other activities that are crucial parts of innovation process in a certain system of innovation (Woolthuis et al., 2005, 610).

Despite the prior efforts to *define* what systemic problems are (Carlsson and Jacobsson, 1997; Norgren and Hauknes, 1999; Smith, 2000; Woolthuis et al., 2005), to our knowledge, no attempt has been made thus far to empirically *identify* or *measure* problems in a specific system of innovation. This paper aims at contributing to filling this gap by analysing problems in the Thai innovation system. Thailand is an interesting case study, since the country, unlike the East-Asian Tigers, is a less-successful country in terms of technological catching up with the forerunners. It has also been a latecomer in trying to adopt and implement the IS approach, despite suffering from very clear systemic problems (Bell, 2002; Intarakumnerd et al., 2002). The paper investigates whether there is a mismatch between the systemic problems of the Thai innovation system and the innovation policies implemented in the country since 2001.

In doing so, we use data from the Thai innovation survey in 2003 which seems to allow a sufficient time lag for our analysis to identify systemic problems after a major political transition starting in early 2001, i.e., changing from a traditional research-based policy (pre-Thaksin administration) to a more explicit innovation

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[1] Todtling and Trippl (2005), for instance, argue that there is no "ideal model" for innovation policy and discuss how it can be tailored to specific conditions in different regions.

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system policy (Thaksin era). The Thai innovation survey has a particular advantage as it contains several detailed questions[2] that seem to allow identification of some of the systemic problems in Thailand. We employed hierarchical factor analysis in identifying institutional, S&T infrastructure, support services and network components/problems. These system components were then linked to a qualitative description of the real situation in Thailand in the discussion of whether there is a mismatch between Thai innovation policy instruments and the systemic problems captured.

The rest of the paper is organised as follows. In the next section, we give a brief summary of the IS approach and discuss its implications for innovation policy, and we introduce some major systemic problems as the prior studies pointed out. Section 3 provides an overview of the Thai innovation system and policy. Section 4 gives a general account of the Thai innovation survey and describes the dataset used and the questions selected to capture system subcomponents and system components. In Section 5, we provide descriptive evidence, present our hierarchical (two-stage) factor analysis, identify and measure problems of the innovation system and discuss them in the light of the recent transformation of the Thai innovation system and innovation policy. Section 6 matches the systemic problems found with some of the main current policies in Thailand. The paper is rounded up in Section 7 with conclusions and some final remarks.

2. Innovation systems and innovation policy

2.1. Main assumptions of the innovation system approach and policy implications

Since the seminal works of Freeman (1987), Lundvall (1988, 1992), Nelson (1993) and Edquist (1997) in the eighties and the nineties, the innovation system approach has gained much scholarly attention and has been largely adopted by practitioners and policy makers in both developed and developing countries (Lundvall et al., 2006; Muchie et al., 2005; Mytelka and Smith, 2002; Edquist and Hommen, 2008). In this framework, the innovation process is seen as sophisticated, involving various dynamic arrangements and links between system components, which essentially enables knowledge sharing and other support for the firm's innovation activities. Systemic agents and components, such as firms, users, universities, public organisations, institutions and so on, usually vary from region to region, sector to sector and country to country (Lundvall, 1988, 1992). Learning might stem from internal research and interactions with Science and Technology providers (Science and Technology to Innovation – STI mode of learning) as well as from daily working routines, i.e., learning by Doing, Using and Interacting (DUI mode of learning) (Jensen et al., 2007).

The general policy implications of the IS approach are different from those of the neoclassical theory in terms of rationales (Chaminade and Edquist, 2010), objectives and instruments (Borrás et al., 2009) for policy-making. The major conflict between the IS and neoclassical approaches to innovation policy stems from the rationales for public intervention. Scholars in the neoclassical tradition suggest that the policy maker needs to intervene in case of market failure, i.e., when the market cannot reach or return to an optimal equilibrium. According to this approach, the policy maker acts as if he or she has an entire set of accurate, necessary information at hand and, therefore, can supply a general set of rationalised solutions to direct the firm's behaviour and other market conditions (Metcalfe, 1995a,b), with the main goal to bring the economy (back) to a Pareto optimum.

The proposal from the IS perspective is, on the other hand, not to base the policy rationale on market failures (Lundvall and Borrás, 2004), but instead on systemic problems.[3] The scholars in the IS and evolutionary economics traditions reject the notion of optimality (and thus that of equilibrium or failure).[4] Innovation process is path-dependent and context-specific, and it is not possible to specify an ideal or optimal IS (Chaminade and Edquist, 2006). Policy making (on the evolutionary basis), thus, needs to be adaptive and experimental, but not optimising (Metcalfe, 1995a). The IS scholars put forward that since the concept of optimality is not to be applied, policy makers are expected to intervene when the system cannot achieve the objectives of supporting the development, diffusion and use of economically useful knowledge and innovations (Edquist, 1997; Lundvall, 1992), i.e., when some systemic problems exist.

Some may interpret that the hidden assumption in this logic is that policy makers have complete information and would know what the problems of the system are. This is far from reality. Policy makers have very limited information about the functioning of their system of innovation. As a consequence, policy makers have to attempt and reattempt to implement different policy options that may influence the firm's (innovative) behaviour as well as other actors in the system. This evolutionary process is obviously characterised by a large extent of trial and error (Metcalfe and Georghiou, 1998). The very issue in this context is "how well policy makers learn and adapt in the light of experience" (Metcalfe, 1995a, 31), and how well can they analyse and interpret the (limited) information that they have on their innovation system.[5]

2.2. Systemic problems and their identification

Although the literature on systemic problems is scarce and dispersed, attempts have been made to *theoretically* discuss some potential major problems in the system all related to either the components of the system (organisations, institutions or relationships) or to the evolution of the system over time, although none of the studies hitherto offer any empirical evidence of such problems or suggest how they can be identified empirically.

Although almost each author has his or her own list of potential systemic problems, they can be pinned down to infrastructure problems, capability problems, network problems, institutional problems and transition and lock-in problems (Chaminade and Edquist, 2006).

Infrastructure problems refer mainly to an inadequate provision of research and innovation infrastructure. From the policy perspective, there might be a research infrastructure problem if, for example, the universities lack capabilities to conduct research; if there are not R&D centres; if the links between university and

[2] These include the questions on, for example, institutional support and innovation environment not available in the standard Community Innovation Surveys (CISs) in Europe.

[3] As indicated in Chaminade and Edquist (2006), we prefer the term 'system problem' to 'systemic failure'. This is to avoid any possible connection with the neo-classical notion of "optimality".

[4] One may argue that to apply the evolutionary theory alone is already sufficient in setting a sound framework for innovation policy making. In our view, many of its theoretical elements might be difficult for policy makers to comprehend and, for this reason, the IS concept, which has proved central to the evolutionary approach (Metcalfe, 1994), is nowadays essentially used as a language tool for the communications between IS and evolutionary, theorists/researchers as well as policy makers.

[5] This paper is related to this last purpose. We do not claim that we are proposing a method to identify systemic problems as this will imply that we have perfect information about the system. Rather, we propose a method to better explore and analyse existing information to provide a better (but not optimal) picture of some problems in the system.

industry are ill developed, etc.[6] What the literature seems to ignore is the fact that the mere existence of weak links between universities and industries, for example, might not constitute a (systemic) problem in a country where the main economic activities are not based on research.[7]

Even when fairly well functioning research and innovation infrastructure exists, firms may not be able to absorb the knowledge generated by other organisations in the system because they have *capability problems*, that is, low levels of scientific and technological capabilities or problems with the complementarity or diversity of the capabilities. In the absence of technological capabilities and therefore sufficient absorptive capacity, knowledge transfer can hardly exist, and, as a result, no systemic interactive learning may take place (Polanyi, 1966; Cowan et al., 2000; Szulanski, 2003). In addition to the firm's own capabilities, firms and other organisations need to be part of formal and informal networks.

Network problems refer to the nature as well as intensity of linkages. On the positive side, strong ties may facilitate the transfer of complex knowledge, but, on the negative side, if the linkages are too strong, the organisations might, on the other hand, be too blind to see what happens within other networks (in the IS) (Woolthuis et al., 2005). Furthermore, even when networks exist, the organisations in the system will have limited incentives to share knowledge (Nooteboom, 2000) if the cognitive distance is too high. While the literature on IS in developing countries has largely emphasised the network problems in the countries' systems of innovations (Intarakumnerd et al., 2002), it has seldom questioned which links specifically matter in a particular system of innovation. For example, one could argue that a weak university–industry linkage for research may not be a problem in traditional industries while it may be a very important hindrance for science-based industries. From a policy perspective, it is important to understand whether the existing linkages are adequate in supporting both DUI and STI modes of learning, whether they facilitate the transfer of both tacit and codified knowledge, and whether the partners have the adequate cognitive distance.

Institutional problems refer to ill-developed institutional frameworks or even absence of some institutions needed for the innovation process like formal rules (e.g., regulations and laws) and more implicit ones (e.g., social norms and political culture), respectively. There are only a handful of scholars that have explicitly discussed the role of institutions in systems of innovation (Johnson et al., 2003; Oyelaran-Oyeyinka, 2006; Lundvall et al., 2006). We still have very limited empirical-based evidence on how institutions affect innovation, and this gap is particularly outstanding for developing countries.

Finally, *transition* or *lock-in* problems are linked to the path–dependent characteristic of the system. Transition problems occur when firms are not able to respond suitably to new technological opportunities or emerging problems because of their very limited technological knowledge or because they are based on very old technology (Smith, 2000). This is frequently the case in developing countries where most firms are adopters of mature technologies rather than producers of new ones. On the other hand, the concentration of capabilities in a certain technological field can result in another type of systemic problem, i.e., the lock-in of the system. In this respect, systems might be locked in some particular technological trajectories that impede firms from taking advantage of new technological opportunities (Smith, 2000; Narula, 2002).

[6] This list is not exhaustive. It is only an illustration of policy dilemmas regarding research infrastructure.

[7] As indicated earlier, what constitutes a problem is determined by the specific characteristics of the socio-economic environment and the composition and functioning of the system of innovation.

As demonstrated in this brief review, the literature so far has only superficially sketched out the kinds of systemic problems that are likely to arise in innovation systems. Most of this sketching has been primarily theoretical, and where empirical evidence is provided it is more illustrative than systematic. Moreover, such limited empirical material is primarily illustrative of experience in the advanced economies. The main purpose of the present paper is to propose a method to empirically identify systemic problems, to test it in the Thai innovation system (during 2003) and to discuss how adequate, if at all, the current portfolio of policy instruments appears, given the problems identified in the analysis. In the following sections, we introduce the Thai innovation system, we propose a framework to identify systemic components and assess the extent to which they might be problems, based mainly on data from the Thai innovation survey in 2003.

3. An overview of the Thai innovation system and policy

It can be said that Thailand is a developing country which has been successful in terms of industrialisation. The country's status was upgraded from low-income to lower-middle-income in the year 2005, with Gross National Product (GNP) per capita of approximately 2700 US dollars ('Bank of Thailand', n.d.). Thailand's economic performance during the past 40 years has been moderately impressive, judging by the average GDP growth of around 7%. Like the four Asian Newly Industrialised Economies (NIEs), including Korea, Taiwan, Singapore and Hong Kong, Thailand has changed its economic structure from agriculture-based to one in which the industrial (manufacturing in particular) and service sectors have distinctive significance. In addition, following the Asian NIEs, a change in the composition of Thai exports occurred. The share of once-dominating resource-based and labour-intensive exports has declined, while that of science-based and differentiated exports has increased, especially during the 1990s (Intarakumnerd, 2006).

However, unlike the Asian NIEs, Thailand has performed badly in terms of research and innovation. *Firms* in Thailand have low technological capabilities (Intarakumnerd et al., 2002; Arnold et al., 2000), especially those in the SME group. According to the Thai R&D and innovation survey carried out for the year 1999, less than 15% of the firms had conducted R&D, only one third had reverse engineering capabilities and only half indicated that they had some design capabilities. In addition, Thai *universities* have very low research performance as measured by the number of publications in recognised international journals (Intarakumnerd et al., 2002). *Linkages* between users and producers, between firms in the same and related industries and between universities (and research centres) and industries are also weak. These are examples of specific weaknesses of the Thai innovation system.

Prior research shows that the relatively low innovative performance of Thailand – compared to the Asian NIEs – is partly due to the lack of adequate policies that target such weaknesses (Arnold et al., 2000; Bell, 2002; Intarakumnerd et al., 2002; Intarakumnerd, 2005). The linear model of innovation and neoclassical rationales had predominately influenced Science and Technology (S&T) policy formulation in Thailand for many decades before the turn of the new century, i.e., the country's S&T policies remained more or less unchanged even until 2001. Policies to support innovation had a clear bias towards (mere) research, covering only four conventional functions: research and development (mainly in universities and public research institutes); human resource development in general (not targeting specific industrial needs); technology transfer from public research institutes to private companies (but much less focus on knowledge/technology produced within and transferred among firms); and general S&T infrastructure development (but not other support infrastructure). The main purpose of these policies was to enhance research capability of governmental R&D institutes and universities, since their potential outputs were believed to be easily transferable to private firms. Remarkably, policies that targeted building up the indigenous technological capabilities of private firms were nearly absent (Bell, 2002). It was considered that S&T knowledge was to be produced mainly by universities and government agencies, while private firms would have a role as only 'users' of this knowledge (Arnold et al., 2000).

In 2001, there was a major shift in the orientation of research (and innovation) policy. The new Thaksin government tried to enhance the nation's international competitiveness by strengthening the 'external' side of the Thai economy, for example, focusing on export, foreign direct investment and tourism. At the same time, the new government attempted to increase capabilities of domestic and grass-root economies. From the policy perspective, importantly, the concept of innovation system was, to a certain degree, 'formally' adopted during this government. The nation's innovative capability was regarded as a very important factor supporting Thailand's international competitiveness. In particular, building an 'innovative nation with wisdom and learning base' was one of Thailand's seven dreams included in an ambitious project implemented by the government (Phasukavanich, 2003). The ten-year Science and Technology Strategic Plan for 2004–2013 placed the concepts of a National Innovation System and industrial clusters at its heart (NSTDA, 2004). The scope of this current plan has a much broader coverage than the four functional areas that characterise the (research-based) policy of the previous decades. The 2004–2013 plan, proposing to put more efforts in stimulating innovation and strengthening National Innovation System, was based on the following main policy objectives (NSTDA, 2004), which include:

- Augment the technological capability and productivity of Thai firms.
- Increase the number and quality of researchers in universities, research institutes and firms.
- Strengthen grass-root initiatives and economies.
- Improve the S&T management system.

As mentioned in the plan, some of the main instruments to stimulate innovation in Thailand were the following[8] (Intarakumnerd and Chaminade, 2007): 200% tax concession for R&D expenditure; accelerated depreciation for R&D machinery and equipment; deduction/exemption of R&D machinery import duties; tax holidays for investment in R&D activities, soft loans for R&D investment in firms; establishment of seven centres of excellence for educating postgraduate research students; Board of Investment's (BOI's) Skill, Technology, and Innovation Scheme[9]; Industrial Technology Assistance Program (ITAP)[10]; BOI's special tax concession scheme for hard disk drive and semiconductor clusters[11]; cluster initiative and a series of initiatives to support grass-root economies like the Village Fund or the People's bank[12] or schemes for the mobility of personnel between the different agencies. The relationship between the instruments and the objectives of the S&T policy is summarised in Table 1.

Table 1
Objectives and instruments of S&T policy in Thailand.

Objective	Related instruments
Augment the technological capability and productivity of Thai firms	R&D tax incentives; Soft loans for R&D investments; Industrial Technology Assistance Program (except 'program' in computers); Clusters; Regional Science parks and incubators
Increase the number and quality of researchers	Creation of excellence centres; R&D tax incentives for training
Strengthen grass-root initiatives and economies	The Village Fund; The People's Bank
Improve S&T management system	Mobility of staff between policy agencies

Moreover, the Thaksin government also had impacts on other actors interacting with the government. The private sector organisations, for example, began to acknowledge the importance of clusters and tried to use the cluster concept to formulate and implement their strategies. The Thai Chamber of Commerce and Federation of Thai Industries started to carry out their activities cluster-wise and reorganise their internal organisations according to clusters (Intellectual Property Institute, 2003). Similarly, public research organisations and universities were also under pressure from the Thaksin government and the Budget Bureau to increase their revenue; hence, reducing their reliance on the national budget. They were forced to become more relevant to industrial needs in order to earn extra income.

Nonetheless, as Intarakumnerd and Chaminade (2007) point out, the innovation policy instruments that were actually used reflect a narrow, rather linear approach to innovation, since they placed considerable emphasis on research-based activities and much less on innovation in a broader sense; i.e., in a way that involves other forms of learning, for example, on-the-job learning or learning by doing. This implies a gap between the rationale (based on innovation system thinking) in the making of and the instruments eventually applied to implement the Thai innovation policy. In Section 6, we will specifically confront this approach to policy with the results of the factor analysis in order to examine the extent to which policy appears to be addressing the main system problems identified.

4. Data

R&D and Innovation Surveys have been carried out periodically in Thailand since 1999 by the National Science and Technology Development Agency (NSTDA). While R&D surveys have been launched every year for about a decade, so far there have been three waves of Thai innovation surveys in 1999, 2001 and 2003, the fourth one currently being undertaken. The first innovation survey in 1999 covered only manufacturing firms. Since 2001, the scope was expanded to include firms in the service industries. The Thai surveys follow the definitions and methodologies used by OECD (i.e., Frascati Manual 1993 and Oslo Manual 1997) and other countries in Asia conducting similar surveys (i.e., Singapore,

[8] For a detailed discussion of the specificities of these instruments (Intarakumnerd and Chaminade, 2007).

[9] Firms can enjoy one or two year extra tax incentives if they perform the following activities in the first three years: spend at least 1–2% of their sales on R&D or design; employ scientists or engineers with bachelor degree (or higher) in at least 5% of their workforce; spend at least 1% of the total payroll on training for their employees; and spend at least 1% of the total payroll on training personnel from their local suppliers.

[10] The ITAP program is aimed at finding suitable consultants from domestic universities/research institutes or abroad to help firms solve their production problems and enhance their technological and innovative capabilities. Up to 50% of the consultancy costs are subsidised by the public. This program in part helps forging linkages between university professors and firms.

[11] This was a new scheme launched in 2004. It was the first time that Thailand had an incentive for particular clusters (beneficiaries being both final-good producers and component suppliers in the clusters).

[12] These include, for example, Village Fund (one million Baht to each village to increase its local capabilities); a three-year debt moratorium on farmers' debt; One Tambon One Product Project (supporting each Tambon to have product champions); and People's Bank (giving loans to underprivileged people with no requirement of collateral).

Malaysia, Japan, Taiwan and Korea). In the Thai case, the sampling methodology was developed based on the business on-line (BOL) database, which contains comprehensive information of approximately 50,000 establishments registered with the Commercial Registration Department so as to obtain unbiased estimates of the population R&D/Innovation parameters, for example, R&D and innovation personnel and expenditures in manufacturing and service firms.

The data from the third innovation survey in Thailand used in this paper has a time span of one year (i.e., throughout the year 2003 only). In Thailand in 2003, the size of the total firm population was 21,653, and the sampling frame for the Thai innovation survey included 6031 firms in total with 4850 from manufacturing and 1181 from the service sector. The overall response rate of 42.8% (42.3% for manufacturing and 45.0% for service firms) was deemed satisfactory, and the original dataset of firms participating in the third Thai innovation survey thus consists of 2582 firms. All were included in a large part of our study. To the extent possible, we include both innovative and non-innovative firms. Non-innovative firms may not yet have engaged in innovation activities because of systemic problems; thus, their perception of what those systemic problems may be is important for this analysis. Unfortunately and due to the structure of the Thai questionnaire (the same limitation applies to most, if not all, European CIS questionnaires), only the innovative firms are asked to answer questions related to innovation activities, and, consequently, the analysis based on these questions is restricted only to innovative firms.

The literature review on systemic problems suggests that there are mainly five systemic problems: infrastructure problems, capability problems, network problems, institutional problems, and transition and lock-in problems. For the analysis in this paper, we went through the Thai questionnaire and selected all those questions that provided some information about the impact of infrastructure on the innovation process, the S&T capabilities of the firm, the networks for innovation and the role of the institutions in the innovation process. Due to the cross-sectional nature of the data, we will not be able to analyse whether there are any lock-in or transition problems in the Thai innovation system. There are basically 4 questions in the questionnaire that provide information on the role of infrastructure, networks and institutions and those are the ones on business environment for innovation in Thailand, government support for innovation in Thailand, obstacles for innovation in Thailand and sources of information for innovation. It is important to note that there is not one specific section on infrastructure, for example, but issues regarding the role of the infrastructure in the innovation process can be found in the questions on the business environment, the government support or the obstacles for innovation. With regards to the capabilities, we use the data on innovation intensity, R&D intensity and the share of scientists and engineers over total employees.

The first question considered for the analysis asked firms "How do you assess the current business environment in Thailand for R&D and other innovation activities?" In the following text, we refer to this question as Question 1. *Business Environment for Innovation in Thailand.* Firms were asked to use a five-point scale, 1 being very weak and 5 very strong (and zero indicating 'do not know'). The complete list of options included in this question is listed in Table 2. It included, among other issues, the Openness to Innovation of clients and suppliers, financial situation, regulations, qualified workers, venture capital, support from universities, R&D institutes and other organisations).

The second question used in the analysis is what we call Question 2. *Government support for Innovation in Thailand*. In the survey, the firms were asked to "indicate which," if any, of the services and incentive programs provided by the government agencies/support networks indicated below your company has used for supporting

Table 2
List of variables employed in the hierarchical factor analysis (with their mean statistics/percentage of firms that have responded to that specific question = 1).

	Innovative firms (%)	Non-innovative firms (%)
Variables used in 1st stage factor analysis		
Question 1. Business environment for innovation in Thailand (1/0)		
Government incentives for innovation	0.15	0.16
Suitable manpower in scientific/technological sector	0.21	0.17
Suitable manpower in business sector	0.26	0.26
Supplier's technical sophistication	0.21	0.20
Consultancy support services	0.17	0.15
University technical support and collaboration	0.18	0.14
R&D institution technical support and collaboration	0.21	0.14
Other technical supporting services	0.13	0.11
Acceptance of failure	0.09	0.12
Attitude of people towards innovation	0.36	0.22
Openness of customers to innovation	0.47	0.30
Openness of suppliers to innovation	0.36	0.27
Regulations	0.16	0.20
Intellectual property protection	0.21	0.29
Telecommunications and IT services	0.29	0.32
Finance for innovation	0.23	0.20
Listing requirements on stock exchange	0.08	0.17
Question 2. Government support for innovation in Thailand (1/0)		
Industrial consultancy services	0.36	0.13
Technology transfer arrangements	0.18	0.06
Loans and grants	0.13	0.04
Support for quality systems	0.34	0.11
Testing and analytical services	0.40	0.10
Information services	0.51	0.19
Support for human resource development	0.36	0.12
Tax deduction for training	0.16	0.07
Tax deduction for R&D activities	0.05	0.02
Question 3. Obstacles to innovation in Thailand (1/0)		
Internal factors		
Perceived risk too high	0.27	0.33
Perceived cost too high	0.54	0.44
Limited financial resource	0.39	0.37
Lack of information on technology	0.46	0.39
Lack of information on market	0.40	0.44
External factors		
Lack of qualified personnel	0.43	0.42
Inadequate support services	0.38	0.33
Lack of government support	0.46	0.32
Lack of customer's interest in innovation	0.21	0.42
Lack of competition in the domestic market	0.18	0.34
Question 4. Sources of information for innovation in Thailand (1/0)		
Within the company	0.70	
Parent/associate companies	0.45	
Clients	0.68	
Local suppliers	0.42	
Foreign suppliers	0.40	
Universities/academic institutes	0.20	
Public research institutes	0.22	
Private non-profit institutes	0.12	
Business Service Providers	0.17	
Technical Service Providers	0.26	
Competitors	0.45	
Patent disclosures	0.18	
Fairs and exhibitions	0.40	
Professional conferences	0.36	
Specialist literature (e.g., journals)	0.35	
Internet	0.58	
Variables added in 2nd stage factor analysis		
Innovation intensity (innovation expenditure per employee in Baht)		
R&D intensity (R&D expenditure per employee in Baht)		
Knowledge worker intensity (proportion of scientists and engineers in total employees %)		
Number of firms	184	2398

R&D and other innovation activities". The list of services that is included after the question for the firms to evaluate includes among others, various technical and consultancy services, technology transfer arrangements, and tax incentive. These variables are dummy variables with the value 1 if the firm has used the incentive program and otherwise they have the value zero.

The third question used for the analysis is what we call Question 3. *Obstacles to innovation in* Thailand. The specific question to the firms was: "Please indicate the importance of the following as factors limiting innovation within your company in 2003" using a five-point scale with zero indicating 'not relevant', 1 'not important' and 5 'very important'. A list of options followed the question, distinguishing between internal (perceived risks or costs too high, limited financial resources, lack of information on market or technology) and external factors (lack of qualified personnel, inadequate support services, lack of government support, lack of customer's interest in innovation or lack of competition in the domestic market). The complete list of options included in this question is in Table 2.

Finally, the fourth question used for the analysis is what we call Question 4. *Sources of Innovation*. The specific wording of the question in the survey is "Please indicate the degree of importance of the following sources of information to your R&D and other innovation activities in 2003" and the firms were given also a five-point scale ranging from 1 'not important' to 5 'very important', with zero indicating 'not relevant'.

Besides these sets of questions, we include variables that are spread all over the survey questionnaire to capture the problems of capabilities, like the innovation expenditure, R&D expenditure and the proportion of scientists and engineers in total employees (as a percentage). For the analysis, we also use categorical information such as size and sector.

The analysis covers variables of many types, including binary, Likert-scale and continuous variables. For the sake of consistency and solving a scaling problem in the Thai innovation survey 2003 questionnaire,[13] all Likert-scale (0–5) variables were transformed to dummies, i.e., values 4–5 were re-coded to 1 and otherwise to 0. This technique has also been applied in prior factor analysis studies using data from the European CIS.[14]

5. Analytical method

This section first explains the approach we have taken to the main method of analysis – factor analysis – that makes it possible to identify groups of correlated variables. Following Srholec and Verspagen (2008), we used a two-stage, hierarchical procedure to identify higher-order factors that are based on correlated lower-order factors computed from a large number of original variables. In this procedure, the first stage was performed for each of the four groups of variables in Table 2.[15] The purpose was to group a number of variables in few (lower-order) factors, which may help explaining some characteristics of subcomponents of the Thai innovation system (see below). Subsequently, factor scores produced by each first-stage estimate were employed in the second-stage factor analysis to identify main components in the system: that is, higher-order factors that come together (see Table 2).[16] An alternative scheme to the two-stage hierarchical factor analysis is to run factor analysis on all selected variables at once. However, in our sample, non-innovative firms do not have valid information on a number of variables, as acknowledged above, due to the questionnaire structure. In some parts of the analysis, our constrained focus on only innovative firms thus yields a significantly reduced sample size, which is not appropriate for this alternative scheme: that is, it factors a fairly large number of variables at the same time (Cattell, 1978; Guilford, 1954; Gorsuch, 1983) (Table 3).[17,18]

6. Results

6.1. Results from first-stage factor analysis

In this section, we present the factor analysis for each of the 4 questions included in Table 2, which we want to reduce. The following Tables 4–7 show, respectively, the results of the factor analysis for each of the 4 questions, that is, Question 1. Business environment for innovation in Thailand, Question 2. Government support for innovation in Thailand, Question 3. Obstacles to innovation in Thailand and Question 4. Sources of information for innovation in Thailand.

We labelled the subcomponent 1 as 'Knowledge Resource', as it refers to system elements that supply knowledge for innovation activities in firms. This first sub-component loads highly on the technological sophistication of suppliers and the availability of suitable manpower. In particular, the results concerning the latter are consistent with the recent studies highlighting that firms in Thailand consider the lack of qualified human resource, especially within the area of Science and Technology, as a very serious problem (see for example, TDRI, 2004; Chalamwong et al., 2007; NESDB, 2007).

We labelled the subcomponent 2 as Technical support as it refers mainly to technical support and collaboration from other organisations. For innovative firms, consultancy support, which has a high factor loading for the subcomponent 1 (knowledge resource), seems to correlate also (though to a lesser extent) with other support shown with high factor loadings in the subcomponent

[13] Scaling is problematic in some parts of the Thai innovation survey 2003 questionnaire. For instance, '0' answers have inconsistent meanings in different questions, i.e., they could be 'not relevant' or 'do not know'. In addition, some questions have '0' coded for 'not relevant' while '1' for 'not important'. We opted to consider the 0 responses as missing values and following similar studies on the obstacles to innovation (Baldwin and Lin, 2002; Galia and Legros, 2004), to recode values 4 and 5 (important or very important) as 1 and the rest as 0. Unfortunately there is a loss of information inherent to the re-coding but since our paper is concerned with systemic problems, it makes sense to make a distinction between those factors that are important or very important (recoded as 1) and those that are not (recoded as 0) while solving the problem with the wording used in the scaling of answers and its interpretation.

[14] Although factor analysis was initially developed to work only with continuous data, more recent developments and techniques allow the computation of factor analysis with categorical and even dummy variables. Some examples can be found in Leiponen and Drejer (2007), Hollenstein (2003, 2004) or Clausen et al. (2010).

[15] The alternative strategy of using factor analysis on all of the variables at once is not feasible with this data set as we have a relatively small number of cases with a large number of variables. The result of the factor analysis using all the variables at once is 18 factors (with eigenvalue >1). If we force the program to find 4 factors, the resulting factors are quite similar to the ones obtained by the two-step but adds some variables that are difficult to interpret. Instead, with the two-step hierarchical factor analysis we introduce more structure to the latent objects that are being estimated at each level.

[16] Oblique rotation deemed as an appropriate method allowing factors to correlate was employed throughout the analysis. However, unlike that in Srholec and Verspagen (2008), tetrachoric and polychoric correlations suitable for factor analysis involving both binary and Likert-scale variables were not used in our case because these correlations lead to problems in the analysis when the sample size is somewhat small, which is the case in our study.

[17] For example, Gorsuch (1983), Cattell (1978) suggest having five, six and ten observations, respectively, per one variable included in factor analysis.

[18] Using all variables at once in SPSS 16.0, it failed to produce a factor solution (due to the small sample size). Using STATA 10.0, we experienced the 'splintering of factors', that is, a factor solution led by many smaller groupings of variables which, in fact, could have formed a larger factor. This appears to support the choice of methodology for our analysis.

Table 3
The hierarchical (two-stage) factor analysis: the broad results.

	Input variables:		*Output Factors*
First stage	1. Business environment for innovation	(17) →	5 factors
	2. Government support for innovation	(9) →	3 factors
	3. Obstacles to innovation	(10) →	3 factors
	4. Sources of information for innovation	(16) →	5 factors
	Total number of variables	***(52)*** →	**16 Total Factors**
Second stage	1.The 16 factors resulting from the first stage 2.Four additional variables: - venture capital, - R&D intensity, - innovation intensity - knowledge worker (intensity)		4 factors - Institutional, - S&T infrastructure, - Support services - Network.

2, 'Technical Support'. Besides consultancy support, this dimension includes support from and collaboration with universities and other organisations (for both innovative and non-innovative firms). This is reassuring because it is common that universities provide consultancy service to firms. Schiller (2006) found that this is particularly true in the Thai case as consultancy service is the most popular mode of university–industry linkage in Thailand. Generally, it can be said that this subcomponent points to the fact that

Table 4
1st stage factor analysis on business environment for innovation in Thailand, innovative (I) and non-innovative (NI) firms.

	Factors – 'sub-components'									
	1		2		3		4		5	
	Knowledge resource		Technical support		Openness to Innovation		Regulation and other institutional conditions		Financial and IT infra-structure	
Innovative/non-innovative firms	I	NI	I	NI	I	NI	I	NI	I	NI
Government incentives for innovation	0.27	**0.61**	−0.01	0.13	0.17	0.00	0.24	−0.10	−**0.65**	0.15
Suitable manpower in scientific/technological sector	**0.67**	**0.80**	0.19	0.07	0.03	−0.07	−0.02	0.00	−0.02	0.02
Suitable manpower in business sector	**0.69**	**0.80**	0.00	−0.08	0.10	0.08	0.08	0.07	0.06	−0.07
Supplier's technical sophistication	**0.87**	**0.55**	−0.13	0.09	0.01	0.21	−0.02	0.00	−0.08	−0.08
Consultancy support services	**0.61**	0.07	**0.39**	**0.57**	−0.13	0.18	−0.07	0.09	0.04	−0.07
University technical support and collaboration	−0.05	0.00	**0.88**	**0.78**	−0.01	0.04	0.04	0.13	0.05	−0.07
R&D institution technical support and collaboration	0.00	0.03	**0.88**	**0.78**	0.07	−0.01	0.02	0.12	−0.05	−0.01
Other technical supporting services	0.26	0.13	**0.50**	**0.66**	0.00	−0.02	0.22	−0.12	−0.10	0.27
Acceptance of failure	0.19	−0.02	0.09	0.31	−0.03	0.05	**0.55**	−0.08	−0.16	**0.65**
Attitude of people towards innovation	−0.06	−0.07	−0.04	0.08	**0.77**	**0.69**	0.07	0.02	−0.31	0.23
Openness of customers to innovation	−0.02	0.00	0.05	0.00	**0.87**	**0.90**	−0.07	−0.03	0.05	−0.02
Openness of suppliers to innovation	0.18	0.11	0.08	0.00	**0.67**	**0.79**	−0.02	0.03	0.27	−0.06
Regulations	−0.11	0.01	0.03	0.16	−0.11	−0.02	**0.80**	**0.77**	−0.03	−0.03
Intellectual property protection	−0.01	−0.02	0.08	0.05	0.04	0.08	**0.79**	**0.83**	−0.01	−0.02
Telecommunications and IT services	0.11	0.09	−0.02	−0.14	0.25	0.23	0.31	0.20	**0.45**	**0.55**
Finance for innovation	−0.03	0.15	0.17	−0.10	0.23	0.06	**0.42**	**0.37**	0.14	**0.54**
Listing requirements on stock exchange	0.26	0.16	−0.12	−0.03	0.09	−0.10	**0.43**	**0.63**	**0.46**	0.20

Note: For innovative firms, 61.1% of total variance explained, $\chi^2(136) = 971.00$, Prob. $> \chi^2 = 0.00$. For non-innovative firms, 62.4% of total variance explained, $\chi^2(136) = 1.4e+04$, Prob. $> \chi^2 = 0.00$. Method: principal components factoring with oblimin oblique rotation. Numbers in bold indicate moderate to high factor loadings.

Table 5
1st stage factor analysis on government support for innovation in Thailand, innovative (I) and non-innovative firms (NI).

	Factors – 'sub-components'					
	1		2		3	
	Government technical support		Government industrial support		Tax incentive	
Innovative/non-innovative firms	I	NI	I	NI	I	NI
Industrial consultancy services	0.21	**0.73**	**0.72**	0.15	0.10	−0.04
Technology transfer arrangements	0.33	**0.45**	**0.62**	**0.43**	−0.17	0.01
Loans and grants	−0.17	0.06	**0.85**	**0.88**	0.04	0.02
Support for quality systems	**0.67**	**0.72**	0.14	0.16	−0.05	−0.03
Testing and analytical services	**0.75**	**0.73**	−0.05	0.05	0.00	0.02
Information services	**0.52**	**0.84**	0.22	−0.07	0.11	0.03
Support for human resource development	**0.71**	**0.77**	−0.03	−0.13	0.10	0.04
Tax deduction for training	0.24	0.15	−0.12	−0.18	**0.76**	**0.81**
Tax deduction for R&D activities	−0.11	−0.12	0.10	0.17	**0.90**	**0.86**

Note: For innovative firms, 60.5% of total variance explained, $\chi^2(36) = 329.19$, Prob. $> \chi^2 = 0.00$. For non-innovative firms, 64.8% of total variance explained, $\chi^2(36) = 6316.48$. Prob. $> \chi^2 = 0.00$. Method: principal components factoring with oblimin oblique rotation. Numbers in bold indicate moderate to high factor loadings.

Table 6
1st stage factor analysis on obstacles to innovation in Thailand, innovative (I) and non-innovative firms (NI).

	Factors – 'sub-components'					
	1		2		3	
	Financial constraint and uncertainty		Lack of information and other support		Hampering market condition	
Innovative/non-innovative firms	I	NI	I	NI	I	NI
Perceived risk too high	**0.70**	**0.54**	0.08	−0.04	0.08	0.33
Perceived cost too high	**0.83**	**0.87**	−0.07	0.03	0.16	0.00
Limited financial resource	**0.75**	**0.85**	0.12	0.08	−0.24	−0.03
Lack of information on technology	0.09	0.32	**0.59**	0.15	0.07	**0.43**
Lack of information on market	0.05	0.29	**0.55**	−0.01	**0.40**	**0.64**
Lack of qualified personnel	−0.06	0.10	**0.72**	**0.58**	0.12	0.27
Inadequate support services	0.09	0.01	**0.79**	**0.85**	−0.05	0.08
Lack of government support	−0.02	0.04	**0.77**	**0.92**	−0.14	−0.10
Lack of customer's interest in innovation	0.14	0.07	−0.07	−0.06	**0.82**	**0.88**
Lack of competition in the domestic market	−0.06	−0.17	0.08	0.20	**0.87**	**0.81**

Note: For innovative firms, 61.0% of total variance explained, $\chi^2(45) = 490.74$, Prob. $> \chi^2 = 0.00$. For non-innovative firms, 70.5% of total variance explained, $\chi^2(45) = 1.2e+04$. Prob. $> \chi^2 = 0.00$. Method: principal components factoring with oblimin oblique rotation. Numbers in bold indicate moderate to high factor loadings.

interactions with the key knowledge producers in the system are important for the firm's innovation process (i.e., the need for knowledge transfer).

The subcomponent 3 was labelled 'Openness to Innovation' as it refers to the attitude of the different Thai system actors' (customers, suppliers and general public) towards innovation. This is an important subcomponent that captures a soft institutional aspect, which is not often addressed in studies based on innovation surveys.

The fourth sub-component is labelled 'Regulation and Other Institutional Conditions' as it embraces indicators of failure

Table 7
1st stage factor analysis on sources of information for innovation in Thailand, innovative firms only.

	Factors – 'sub-subcomponents'				
	1 Universities and non-profit research organizations	2 Supplier	3 Professional knowledge sources and Internet	4 Industry	5 Intra-firm client and competitor
Within the company	−0.11	0.02	0.15	0.05	**0.79**
Parent/associate companies	0.26	0.04	−0.13	−0.10	**0.78**
Clients	−0.06	0.12	0.21	0.17	**0.61**
Local suppliers	0.14	**0.81**	0.01	−0.04	0.08
Foreign suppliers	−0.09	**0.92**	−0.03	−0.01	−0.03
Universities/academic institutes	**0.89**	0.02	0.10	−0.04	0.02
Public research institutes	**0.81**	−0.02	−0.02	0.14	0.09
Private non-profit institutes	**0.44**	0.24	0.08	**0.35**	−0.19
Business Service Providers	−0.06	0.03	−0.02	**0.85**	−0.04
Technical Service Providers	0.19	−0.04	0.08	**0.77**	−0.06
Competitors	0.00	−0.02	−0.09	**0.67**	**0.38**
Patent disclosures	0.26	0.18	0.28	**0.36**	−0.13
Fairs and exhibitions	−0.04	0.09	**0.73**	−0.05	0.08
Professional conferences	0.03	−0.09	**0.90**	0.00	−0.02
Specialist literature (e.g., journals)	0.24	0.02	**0.66**	−0.03	0.01
Internet	−0.16	0.26	**0.50**	0.19	0.19

Note: 67.3% of total variance explained, $\chi^2(120) = 1088.07$, Prob. $> \chi^2 = 0.00$. Method: principal components factoring with oblimin oblique rotation. Numbers in bold indicate moderate to high factor loadings.

acceptance, regulatory environment, intellectual property protection and finance for innovation. In the case of innovative firms, an overlap was found in stock exchange listing requirements as it has a factor loading shared about halfway between this and the last subcomponent, 'Financial and IT Infrastructure'.

Finally, the fifth subcomponent is labelled as 'Financial and IT infrastructure', as it includes government incentives for innovation, communication services for innovation and, as mentioned above, stock exchange listing requirements in case of innovative firms. The result differs somewhat for non-innovative firms as the subcomponent includes acceptance of failure, communication services and finance for innovation. These different results may reflect the share of larger companies among innovative firms versus that of smaller ones among non-innovative firms.[19] Small firms are usually not listed on the stock exchange (e.g., as for the purpose of fund raising). Alternatively, they rely much more on other sources of funding (like business angels), usually located in close proximity to the firm (Crevosier, 1997).[20] Cooke (2002) uses the term 'proximity capital' for this sort of financial infrastructure and, further, suggests its correlation with physical infrastructure like telecommunication services, which supports the results obtained for the case of non-innovative firms. For innovative firms, the results are in fact coherent with our knowledge about the Thai economy. In Thailand, the requirements for stock exchange listing may be, on the one hand, regarded as a regulation and institutional condition (they provide the firms with access to external funding sources for their innovation activities) and as a type of government incentives, on the other. It should be noted, however, that this does not appear to work well for smaller firms. The Thai 'Market for Alternative Investment' (MAI), for example, has been set up to especially foster innovative SMEs since 1999, but the MAI gets little interest from SMEs in practice. One reason is that in this case the founding shareholders are reluctant to enact common stock rights issues that would effectively dilute their stakes in the listed companies (possibly referring to acceptance of failure). Moreover, many SMEs see that the MAI requirements tend to disqualify most small- and medium-sized enterprises for being below the minimum capitalisation level. This instigates a problem as it results in too few outstanding shares to trade adequately on the market (Freeman, 2000).

The results of the first-stage estimate referring to government support for innovation (as discussed above, another set of indicators unique to the Thai case) are presented in Table 5. The factor patterns, which are similar for innovative and non-innovative firms, are summarised as follows.

The label 'Government Technical Support' is given to the first subcomponent retained in this estimate. This subcomponent integrates different services provided by NSTDA and the Ministry of Industry, including information services, testing as well as analytical services and support for quality systems and human resource development. For non-innovative firms, this dimension also includes industrial consultancy services and technology transfer arrangements.

1. The second column presents the group of 'Government Industrial Support', which consists of loans and grants, technology transfer arrangements and industrial consultancy services. However, in the case of non-innovative firms, the last indicator (having a high factor loading in the first column) does not appear to correlate strongly with the other two indicators constituting this dimension.
2. We label the last subcomponent in this estimate 'Tax Incentive', as it combines two tax deduction programs for training and R&D activities which are reported with high factor loadings in both cases.

We continue with a summary of the results in Table 6 reporting the estimations for the Question 3. Obstacles to innovation as perceived by innovative and non-innovative firms. Three subcomponents were retained for the two groups of firms (also with similar factor patterns).

We label the first subcomponent 'Financial Constraint and Uncertainty' as it comprises the firm's perceived high cost and risk as well as monetary limitation. This dimension appears in a similar way for innovative and non-innovative firms.

The second subcomponent is labelled 'Lack of Information and Other Support' as it includes the problems about qualified personnel, government and other support. In this case, the results for innovative firms show that the lack of information on market and technology tends to be relevant to this dimension.

We label the last subcomponent retained as 'Hampering Market Condition', loads highly on the lack of domestic competition, the lack of customer's interest in innovation and moderately on the lack of information on markets. In the case of non-innovative firms, this subcomponent also seems to refer to the lack of information on technology, to some extent.

Now we shift our attention to the last question on information sources for innovation in Thailand. The results of our last factoring estimate in the first stage, which are provided in Table 7 (available for innovative firms only, see a discussion above), present the following five subcomponents.

We label the first sub-component as 'Universities and Non-Profit Research' as it combines information from universities and public as well as private non-profit research institutes. Subcomponent 2 is labelled 'Supplier' as it embraces information from both local and foreign suppliers. The third subcomponent is labelled 'Professional Knowledge Sources and Internet' as it brings together information from the literature, Internet, conferences and other events. The fourth subcomponent loads primarily on competitors and business and technical service providers. We label it 'Industry' as it includes many information sources within the industry. Note that this subcomponent also loads, though only modestly, on patent disclosures and private research institutes. The last subcomponent that we labelled 'Intra-firm, Client and Competitor' correlates mostly with information from clients and from within the company or group of companies, and to some degree with competitors.

6.2. *Results from second-stage factor analysis*

As indicated in the analytical framework, factor scores for all system subcomponents detected in each first stage estimate were computed and used in the second stage factor analysis (innovative firms only, as noted above). In addition, four separate variables were included: (i) a dummy for venture capital/business angle investment received for the firm's innovation activities; (ii) innovation intensity in terms of innovation expenditure over total employees; (iii) R&D intensity in terms of R&D expenditure over total employees; and (iv) a proportion of knowledge workers including scientists and engineers in the firm. The results suggesting four distinct but related components in the Thai innovation system are provided in Table 8.

We apply 'Institutional' as a label to the system component in the first column. Consistent with prior literature (e.g., Edquist and Johnson, 1997), this component covers various (hard and soft) institutional subcomponents in the Thai innovation system, including

[19] A detailed statistics available upon request.

[20] Cooke (2002) points out that on the basis of these sources of funding in a small firm, the degree of investment might be a function of the firm's trustworthiness or, in other words, their tolerance to failure.

Table 8
2nd stage factor analysis on systemic factors in Thailand.

One-stage factors	Two-stage factors			
	Factor 1 Institutional	Factor 2 S&T infra.	Factor 3 Network	Factor 4 Support services
Knowledge resource	**0.69**	−0.19	0.08	−0.08
Technical support	**0.63**	**0.35**	−0.12	0.02
Openness to Innovation	**0.42**	−0.18	**0.41**	0.04
Regulation and other institutional conditions	**0.68**	0.06	0.10	−0.06
Financial and IT infrastructure	−0.17	0.19	**0.47**	**−0.36**
Government technical support	0.23	0.22	0.06	**0.31**
Government industrial support	0.31	−0.09	−0.11	**0.39**
Tax incentives	−0.07	−0.04	0.22	0.12
Financial constraint and uncertainty	−0.15	−0.10	0.07	**0.68**
Lack of information and other support	0.02	0.13	−0.03	**0.77**
Hampering market condition	−0.11	−0.21	0.32	**0.39**
Universities and non-profit research	0.07	**0.42**	**0.39**	0.18
Supplier	0.08	−0.14	**0.69**	−0.04
Professional knowledge sources and Internet	−0.02	0.15	**0.63**	0.02
Industry	0.14	0.04	**0.57**	0.14
Intra-Firm, Client and Competitor	−0.07	0.05	**0.53**	−0.02
Venture capital/business angel investment	**0.45**	−0.03	−0.07	0.18
Innovation intensity	0.03	**0.72**	−0.06	−0.05
R&D intensity	0.04	**0.82**	0.05	0.02
Knowledge workers (scientists and engineers)	−0.10	**0.72**	0.01	0.00

Note: 41.35% of total variance explained, $\chi^2(190) = 577.58$, Prob. $> \chi^2 = 0.00$. Method: principal components factoring with oblimin oblique rotation. Numbers in bold indicate moderate to high factor loadings.

knowledge resource, technical support, Openness to Innovation, existing regulations and financial supports, for example, in the form of venture capital or business angel investment.

The second Factor is labelled 'S&T infrastructure' as it refers to technical support, scientists, engineers, universities and research institutes, which seems to be especially relevant for firms scoring high (having high factor loadings) on innovation intensity and R&D intensity. This finding is also coherent with the literature (Pavitt, 1984) which stresses that S&T infrastructure is especially relevant for science-based firms.

We label the third factor as 'Network' as it combines Openness to Innovation of important actors in the Thai innovation system and different sources of information used in the firm's innovation activities. These include not only internal, but also external sources like universities, research institutes, customers, suppliers, competitors, internet, conferences, fairs, exhibitions and so on. This component also seems to correlate, to some degree, with the financial and IT infrastructure.[21]

The last factor is labelled 'support services' and refers fundamentally to uncertainty and the lack of information needed to innovate. Our 'support services' component loads primarily on the lack of technical and market information for innovation, uncertainty (risk and cost perceptions) and technical and industrial support, especially from the government (despite lower factor loadings). This is an interesting result as it, somehow, points to an additional systemic failure not explicitly mentioned in the literature. Additionally to problems of infrastructure, inadequate institutions, low capabilities or weak networks, the innovation system can be malfunctioning when firms and other organisations in the system lack *information* on technological opportunities, market opportunities for new innovations, potential sources of knowledge, etc. This is particularly important in the case of developing countries, in which economic activities are carried out mainly by small- and medium-sized enterprises (SMEs) and in traditional industries. In developing countries, the basic infrastructures might be present, but indigenous firms might not be aware of their existence (Szogs, 2008; Szogs et al., 2008). Therefore, one obvious obligation of the government, especially in this case, would be to facilitate the flow of information among different organisations in the system.

It is interesting to see how the four factors identified in the analysis are related to R&D and innovation intensity as it provides an indication on how important these factors are for research-intensive firms (STI) in comparison to non-research intensive (DUI). The analysis shows that factor loadings for R&D and innovation intensity are always low in the institutional, network and support services dimension, but high in S&T infrastructure. Put in another way, the firms with low R&D and innovation intensity tend to acknowledge problems associated with the former three systemic components. On the other hand, the firms with high R&D and innovation intensity indicate that the availability of adequate S&T infrastructure (or the lack thereof) is more relevant to their innovation. This will be discussed in greater detail in the next section where we look further into the adequacy of the current policy portfolio to stimulate innovation in Thai firms.

7. Matching systemic problems with current policies: identification of a policy agenda

In this section, we attempt to provide implications of the findings for the design of Thai innovation policy. We are particularly concerned with the adequacy of the instruments currently deployed in Thailand to stimulate innovation in firms. Table 9 illustrates some mismatch between the observed problems and the instruments.[22]

Broadly speaking, most of the instruments currently deployed to strengthen the Thai innovation system are still mainly targeted at research-based firms, or they are likely to benefit these

[21] As discussed earlier, many firms, especially SMEs, use their networks to access financial resources. There it would not seem strange to find linkages between the importance of networks, IT infrastructure and financial infrastructure – these are all related to what Cooke and Crevosier consider as 'proximity capital'. However, it is important to note that the information that we have for the Thai innovation survey does not allow us to control for the geographical location of these networks.

[22] It is important to be aware that the analysis conducted in the previous section is based on a firm-based view of the innovation system, and it refers to the factors affecting innovation in firms.

Table 9
Policy instruments vs. systemic problems.

Objective	Policy instrument	Systemic problem mainly addressed	Type of firm likely to benefit from policy
Augment the technological capability and productivity of Thai firms	Clusters	Networking and support services	Innovative and non-innovative firms; non-technology intensive firms
	Regional science parks and incubators	S&T infrastructure	Research-based firms
Increase the number and quality of researchers	Centres of excellence	S&T infrastructure	Research-based firms
	Skill, technology and Innovation STI scheme: tax incentives for R&D investments, employing scientist or engineering, training employees and training local suppliers	S&T infrastructure and institutions	Most of the tax incentives are related to research activities, and so they are likely to benefit research-based firms. However, the tax incentives for training of employees and suppliers can benefit all kinds of firms
Strengthen grass-root initiatives and economies	People bank; Village Fund	Support services	Non-research based firms

firms. This reflects the path-dependent nature of innovation policy making in Thailand, which traditionally focused on stimulating research (mainly outside of the firm). Put simply, the main difference between this plan and the pre-Thaskin plans is that the latter explicitly targets firms.

As pointed out above, for non-research based firms, the main systemic problems relate to the institutional conditions for innovation (including capabilities, hard and soft institutions, networking and support services). However, it seems that the current plan has very limited instruments targeting these problems:

- Network problems between firms and other organisations are addressed through cluster initiatives at local level (e.g., giving financial incentives), but there is very limited support for networking at the local/regional level. Of course, the plan mentions the necessity to promote cluster development in different regions and provinces. Nonetheless, network problems in those areas were not specifically identified. Consequently, no particular policy measures have been devised to solve such problems.
- With regards to institutional problems, the policies are rather limited to tax incentives for training of employees and suppliers (competence building). There are no explicit policy measures promoting Thai society to be more innovative, Thai entrepreneurs to accept high a failure rate in doing innovative businesses, and Thai customers to accept innovative products or new ways of doing things.
- Finally, in connection with support services problems, one of the most critical difficulties faced by the Thai firms is the lack of information on markets, funding opportunities, financial uncertainty, etc. Several industrial development banks were established for this purpose, the four most important ones being the Industrial Finance Corporation of Thailand (IFCT), SME Bank, Small Industry Credit Guarantee Corporation (SICGC) and Innovation Development Fund (IDF). However, some of these financial institutes are not well known to private firms, and they do not have efficient operations because of chronic bureaucratic red tape (Intarakumnerd, 2006).

Considering the differences between innovative and non-innovative firms, it can be said that in the latter case firms perceive the external environment as a more serious innovation impediment. In general, they rely on simple government technology services like testing and quality control. On the other hand, innovative firms have higher absorptive capacity, and so they can benefit more from interactions with other actors in the National Innovation System, such as university and public research institutes. For them, government assistance emphasising the development of higher technological capability, for example in the form of industrial consultancy service and technology transfer support, seems more necessary compared to simple activities offered as government technological services which they can perform on their own.

Although the S&T Plan being implemented incorporates some systemic features, it is still too much biased towards science/research-based activities. This reflects a narrow vision of innovation systems and innovation policy (Chaminade et al., 2009) where innovation is considered to be (almost exclusively) the result of STI mode of learning. However, as the successful examples of countries show (Jensen et al., 2007), most innovative firms combine STI mode with DUI mode of learning as they are both essential to their innovation process. From the policy perspective, an effective innovation system has to provide firms with the different infrastructures required by these two distinct (but related) forms of learning. This implies that, for example, the promotion of S&T infrastructure is as important as other support services; that formal training (subject to tax incentives) is as important as on-the-job training or training by doing; that interaction with universities is as important as interaction with users or suppliers. The analysis of the Thai innovation survey shows that a broad approach to innovation and innovation systems is needed in the making of innovation policy in Thailand (and arguably in other countries as well). The instruments specifically targeted to solve institutional, network and support services problems are currently neglected, but very much needed. This study argues that there is a mismatch between innovation system problems and innovation system policy instruments in the Thai case.

8. Final remarks

The paper contributes to the current debate on rationales for innovation policy and to IS research by providing a framework to identify systemic problems in a given system of innovation and test the framework empirically. In this respect, we use data from the Thai innovation survey conducted in the period after a major change in the IS policy had been initiated. By hierarchical (two-stage) factor analysis, the systemic problems pointed out by prior research were grouped into four components: institution, network, S&T infrastructure and other support services.

The framework and methodology of this research may be applied for similar analyses of systemic problems in other countries using the CIS or similar sources of data. The framework has also proved useful in helping to identify a mismatch between policies and problems. This implies that the framework can be useful also for policy makers trying to identify systemic problems and devise better policies addressing failures or problems in their countries.

Some final cautionary notes are needed. Policymaking needs to be experimental and adaptive (Metcalfe, 1995a), as there is not complete information. Using empirical tools like the one proposed in this paper is a step forward in the identification of some systemic problems, but the tools have some limitations: our empirical exercise is based on firm data only. It could be criticised that we use this (too) limited information to plot a complex picture of the innovation system and innovation system problems, since this may only reflect the firm's viewpoint. Also, factor analysis can only be as good as data allows. Subsequently, the use of this method to analyse innovation survey data does not imply that no other systemic problems may exist; it merely implies that these are the problems we are able to capture on the basis of the available data.

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